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(54) **METHOD FOR PROPORTIONALLY MIXING TWO CRYOGENIC FLUIDS**

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C09K 5/00	(2006.01)
B01F 15/00	(2006.01)

(52) **U.S. Cl.**

CPC ***C09K 5/00*** (2013.01); *B01F 15/00207* (2013.01); *F25J 2280/02* (2013.01); *Y10T 137/0329* (2015.04); *Y10T 137/2509* (2015.04)

(58) **Field of Classification Search**

CPC G05D 11/132; G05D 11/139; G05D 21/02
USPC 137/3, 88, 93; 366/152.1; 62/657
See application file for complete search history.

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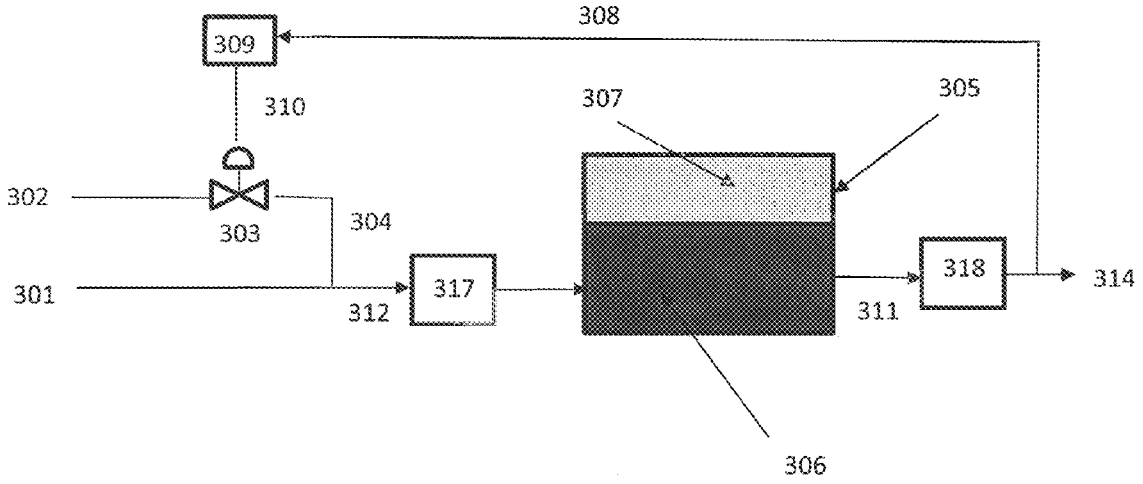
(57) **ABSTRACT**

A method of proportionally mixing two fluids is provided. The method includes introducing a first fluid stream, introducing a second fluid stream, wherein the flow rate of the second stream is modulated by a valve, thereby producing a modulated stream, combining the first fluid stream and the second fluid stream, thereby forming a compounded fluid stream, introducing said compounded fluid stream into a fluid containment region, wherein a vapor fraction and a liquid fraction are formed, determining the composition of the vapor fraction, comparing the composition of the vapor fraction with a predetermined composition to determine a composition error, and modulating the valve to reduce the composition error to a predetermined error.

8 Claims, 3 Drawing Sheets



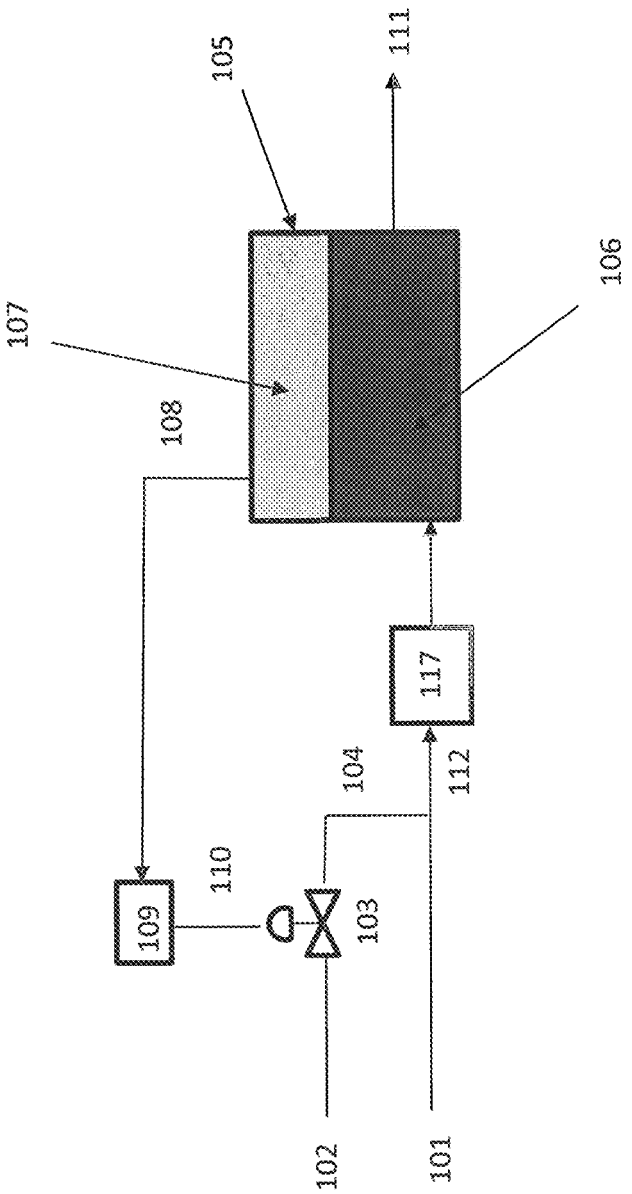


Figure 1

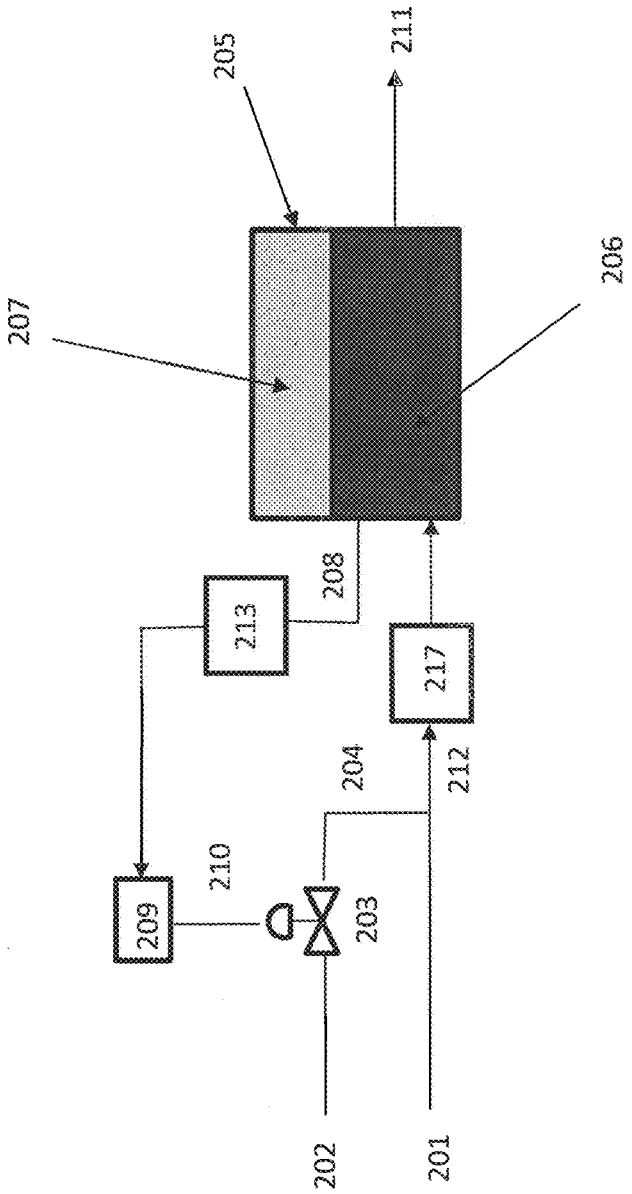


Figure 2

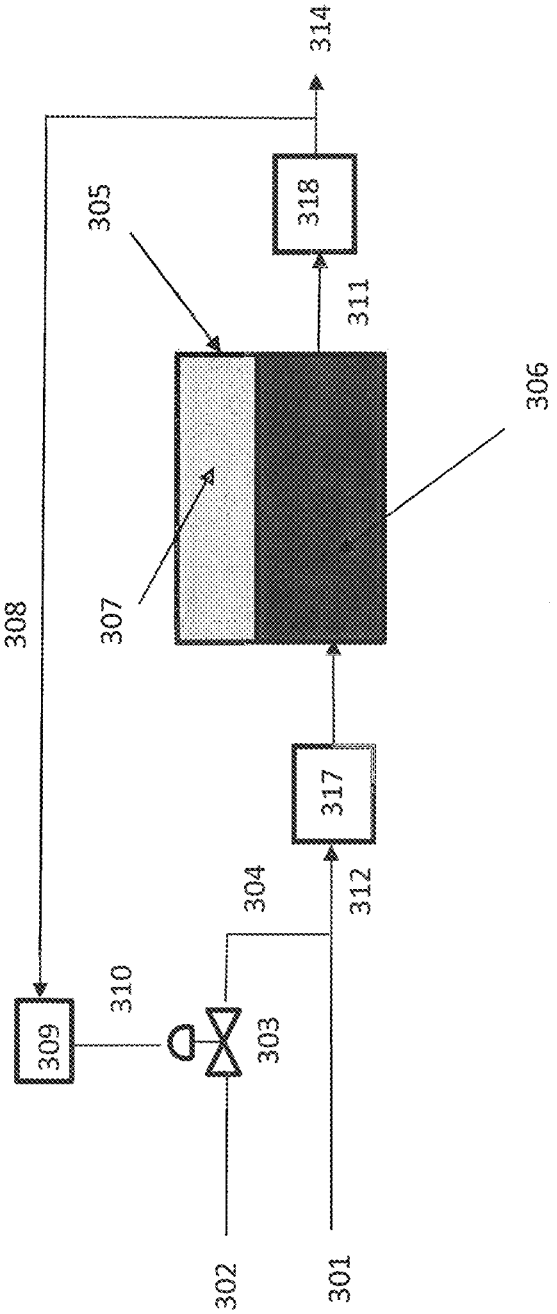


Figure 3

METHOD FOR PROPORTIONALLY MIXING TWO CRYOGENIC FLUIDS

BACKGROUND

There are certain industrial gas applications, such as specialized welding process or cryogenic food refrigeration, where it is advantageous to combine the primary liquid cryogen (for example liquid nitrogen or liquid argon) with a lesser proportion of liquid oxygen prior to delivery of the compounded liquid or prior to the point of use. However, accurate flows of cryogenic liquid are difficult to maintain due to pressure and temperature fluctuations in storage conditions at the supply tank, which impact line pressure and flow rate.

Hence, a need exists in the industry, for a means for proportionally mixing two cryogenic fluids.

SUMMARY

A method of proportionally mixing two fluids is provided. The method includes introducing a first fluid stream, introducing a second fluid stream, wherein the flow rate of the second stream is modulated by a valve, thereby producing a modulated stream, combining the first fluid stream and the second fluid stream, thereby forming a compounded fluid stream, introducing said compounded fluid stream into a fluid containment region, wherein a vapor fraction and a liquid fraction are formed, determining the composition of the vapor fraction, comparing the composition of the vapor fraction with a predetermined composition to determine a composition error, and modulating the valve to reduce the composition error to a predetermined error.

In another embodiment of the present invention, the method includes introducing a first fluid stream, introducing a second fluid stream, wherein the flow rate of the second stream is modulated by a valve, thereby producing a modulated stream, combining the first fluid stream and the second fluid stream, thereby forming a compounded fluid stream, introducing said compounded fluid stream into a fluid containment region, removing a portion of the compounded fluid stream and determining the composition, comparing the composition of compounded fluid stream with a predetermined composition to determine a composition error, and modulating the valve to reduce the composition error to a predetermined error.

In another embodiment of the present invention, the method includes introducing a first fluid stream, introducing a second fluid stream, wherein the flow rate of the second stream is modulated by a valve, thereby producing a modulated stream, combining the first fluid stream and the second fluid stream, thereby forming a compounded fluid stream, introducing said compounded fluid stream into a process, thereby producing a vapor stream, removing a portion of the vapor stream and determining the composition, comparing the composition of the vapor stream with a predetermined composition to determine a composition error, and modulating the valve to reduce the composition error to a predetermined error.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** illustrates one embodiment of the present invention.

FIG. **2** illustrates another embodiment of the present invention.

FIG. **3** illustrates another embodiment of the present invention

DESCRIPTION OF PREFERRED EMBODIMENTS

Illustrative embodiments of the invention are described below. While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

Turning now to FIG. **1**, a method for proportionally mixing two cryogenic fluids is presented. A first fluid stream **101** and a second fluid stream **102** are provided. The first fluid stream **101** and the second fluid stream **102** may be cryogenic. The first fluid stream **101** may be nitrogen. The first fluid stream **101** may be argon. The second fluid stream **101** may be oxygen. The flow rate of the second fluid stream **102** is modulated by valve **103**. The modulated stream **104** is then combined with the first fluid steam **101** to form compounded fluid stream **112**. A static mixer **117**, or any other means known to the skilled artisan, may be used to combine these two streams.

The compounded fluid stream **112** is then introduced into fluid containment region **105**. Fluid containment region **105** may be a tank, a pressure vessel, or a pipeline. A vapor fraction **107** and a liquid fraction **106** may form inside fluid containment region **105**. A sample **108** of the vapor fraction **107** is removed and analyzed **109**, to determine the actual composition of the vapor section. The actual composition may be the percentage of oxygen present in the vapor section **107**. If necessary, a correction factor may be applied to the actual composition of the vapor section **107**, in order to estimate the vapor fraction of the liquid section **106**. The actual composition, or corrected actual composition if necessary, is then compared to a predetermined composition to determine a composition error. If the composition error is greater than a predetermined error, a signal **110** is sent to valve **103**, and the flow rate of modulated stream **104** is either increased or decreased, so as to reduce the composition error and to satisfy the predetermined error. A portion of the liquid **106** may be removed as liquid product stream **111**.

In one embodiment of the present invention, the predetermined composition is between 2% and 22% oxygen, preferably between 5% and 21% oxygen, even more preferably between 10% and 20% oxygen. In another embodiment of the present invention, the predetermined error is less than 5%, preferably less than 3%.

Turning now to FIG. **2**, another embodiment of the present invention is presented. A first fluid stream **201** and a second fluid stream **202** are provided. The first fluid stream **201** and the second fluid stream **202** may be cryogenic. The first fluid stream **201** may be nitrogen. The first fluid stream **201** may be argon. The second fluid stream **201** may be oxygen. The flow rate of the second fluid stream **202** is modulated by valve **203**. The modulated stream **204** is then combined with the first

fluid steam **201** to form compounded fluid stream **212**. A static mixer **217**, or any other means known to the skilled artisan, may be used to combine these two streams.

The compounded fluid stream **212** is then introduced into fluid containment region **205**. Fluid containment region **205** may be a tank, a pressure vessel, or a pipeline. A vapor fraction **207** and a liquid fraction **206** may form inside fluid containment region **205**. A sample **208** of the liquid fraction **206** is removed, vaporized in vaporizer **213**, and the vapor analyzed **209**, to determine the actual composition of the vapor section. The actual composition will be the percentage of oxygen present in the liquid section **206**. The actual composition is then compared to a predetermined composition to determine a composition error. If the composition error is greater than a predetermined error, a signal **210** is sent to valve **203**, and the flow rate of modulated stream **204** is either increased or decreased, so as to reduce the composition error and to satisfy the predetermined error. A portion of the liquid **206** may be removed as liquid product stream **211**.

In one embodiment of the present invention, the predetermined composition is between 2% and 22% oxygen, preferably between 5% and 21% oxygen, even more preferably between 10% and 20% oxygen. In another embodiment of the present invention, the predetermined error is less than 5%, preferably less than 3%.

Turning now to FIG. **3**, another embodiment of the present invention is presented. A first fluid stream **301** and a second fluid stream **302** are provided. The first fluid stream **301** and the second fluid stream **302** may be cryogenic. The first fluid stream **301** may be nitrogen. The first fluid stream **301** may be argon. The second fluid stream **301** may be oxygen. The flow rate of the second fluid stream **302** is modulated by valve **303**. The modulated stream **304** is then combined with the first fluid steam **301** to form compounded fluid stream **312**. A static mixer **317**, or any other means known to the skilled artisan, may be used to combine these two streams.

The compounded fluid stream **312** is then introduced into fluid containment region **305**. Fluid containment region **305** may be a tank, a pressure vessel, or a pipeline. A vapor fraction **307** and a liquid fraction **306** may form inside fluid containment region **305**. Product liquid stream **306** will leave fluid containment region **305** and be introduced into process **318**, wherein it is vaporized into stream **314**.

A sample **308** of the stream **314** is removed and the vapor analyzed **309**, to determine the actual composition of the vapor section. The actual composition will be the percentage of oxygen present in the liquid section **306**. The actual composition is then compared to a predetermined composition to determine a composition error. If the composition error is greater than a predetermined error, a signal **310** is sent to valve **303**, and the flow rate of modulated stream **304** is either increased or decreased, so as to reduce the composition error and to satisfy the predetermined error.

In one embodiment of the present invention, the predetermined composition is between 2% and 22% oxygen, preferably between 5% and 21% oxygen, even more preferably between 10% and 20% oxygen. In another embodiment of the present invention, the predetermined error is less than 5%, preferably less than 3%.

What is claimed is:

1. A method of proportionally mixing two fluids, comprising:

a) introducing a first fluid stream,

b) introducing a second fluid stream, wherein the flow rate of the second stream is modulated by a valve, thereby producing a modulated stream,

c) combining the first fluid stream and the second fluid stream, thereby forming a compounded fluid stream,

d) introducing said compounded fluid stream into a fluid containment region, wherein a vapor fraction and a liquid fraction are formed,

e) determining the composition of the vapor fraction,

f) comparing the composition of the vapor fraction with a predetermined composition to determine a composition error, and

g) modulating the valve to reduce the composition error to a predetermined error

wherein the first fluid stream and the second fluid stream are cryogenic fluids.

2. The method of claim **1**, wherein the first fluid stream is nitrogen.

3. The method of claim **1**, wherein the first fluid stream is argon.

4. The method of claim **1**, wherein the second fluid stream is oxygen.

5. The method of claim **1**, wherein the step of determining the composition of the vapor fraction comprises determining the percentage of oxygen present.

6. The method of claim **1**, wherein the predetermined composition of the vaporized compounded liquid is between 2% and 22% oxygen.

7. The method of claim **1**, wherein the first fluid stream and the modulated stream are combined by means of a static mixer.

8. The method of claim **1**, further comprising withdrawing a liquid product stream from the fluid containment region.

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